THE EXPLOSIVES ENGINEER

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Forerunner of Progress in Mining, Quarrying, Construction

CONTENTS

GEORGE FLOYD FERRIS—*a biography* 140

GEORGE FLOYD FERRIS—*a photograph* 141

Editorial 142

Mining Copper at Bagdad, Arizona 143
By OLAF HONDRUM

Relocating a Mountain Highway in North Carolina 146
By OSCAR M. DAVIS

Geofragmental Mining Methods in Underground Properties 152
By PHILIP B. BUCKY

Three-In-One Tunnel Blast in a Wisconsin Quarry 156
By JOHN C. RICHARDS, JR.

A Hammer That Breaketh Our Rock 163
By CHARLES F. THOMAS

Views and opinions expressed by the authors of articles in this publication are their own, and they do not necessarily represent those of the publisher.

For many years, Bagdad Copper Corporation's mine in west central Arizona has been worked intermittently as an underground operation, with production on a modest scale. With the entry of the United States into World War II, the corporation adopted an expansion program which included a change from underground mining to open-pit operations. In 1947, pit operations had been developed sufficiently so that underground mining was discontinued.

Today, the ore in the pit is drilled and blasted in benches 50 ft. high on several levels. A series of 7-in.-diameter well drill holes is loaded with Hercules* 30% Extra Dynamite in 5¼ in. by 25-lb. cartridges, primed with plastic Primacord. Blasting results are uniformly satisfactory.

A description of the activities at Bagdad is presented in an article on page 143, by Superintendent Olaf Hondrum.

* * *

An 8-mile section of U. S. Highway 70 in western North Carolina, between the towns of Old Fort and Ridgecrest, winds its way up steep grades on the side of the Blue Ridge Mountains in a long series of sharp curves, hairpin turns, and switchbacks. It is classified as one of the eight worst highway sections in North Carolina.

In the fall of 1951, the State Highway Commission awarded a $2,300,000 contract to W. E. Graham & Sons to grade and drain 6.15 miles of rough, tough terrain across the mountains to relocate and modernize this 8-mile corkscrew section of highway between the towns.

Some of the highlights of this project are summarized by Oscar M. Davis on page 146.

EDITORIAL STAFF: JOSEPH I. HORTY, *Managing Editor;* ELIZABETH M. JOYCE, *Assistant Editor;* GERTRUDE A. DONNELLY, *Assistant Editor;* EDWARD L. GRANT, *Art Editor;* FRANK J. CANOVA, *Production Manager;* CHARLES E. RABENOLD, *Advertising Manager;* THEODORE MARVIN, *Director;* MONTGOMERY R. BUDD, *Associate Director.*

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Another significant contribution to the literature on the mining of minerals has been made by Philip B. Bucky, professor of mining, Columbia University, in his article entitled "Geofragmental Mining Methods in Underground Properties," beginning on page 152. Professor Bucky directs attention to the fact that "in the future a greater portion of our workable ore bodies will be at increasing depths, because the earth's surface is becoming increasingly valuable for living space and for agricultural purposes, and the amount of mineral available for each individual is becoming proportionately less in the light of man's greater demands. . . . As mining depths increase, the load supported by pillars of ore increases and a greater portion of the ore body must be left to support workings while men are there engaged. . . . The determination of an effective, economical solution to the problem of depth is among the most pressing problems facing the underground mining industry today."

Please turn to page 152.

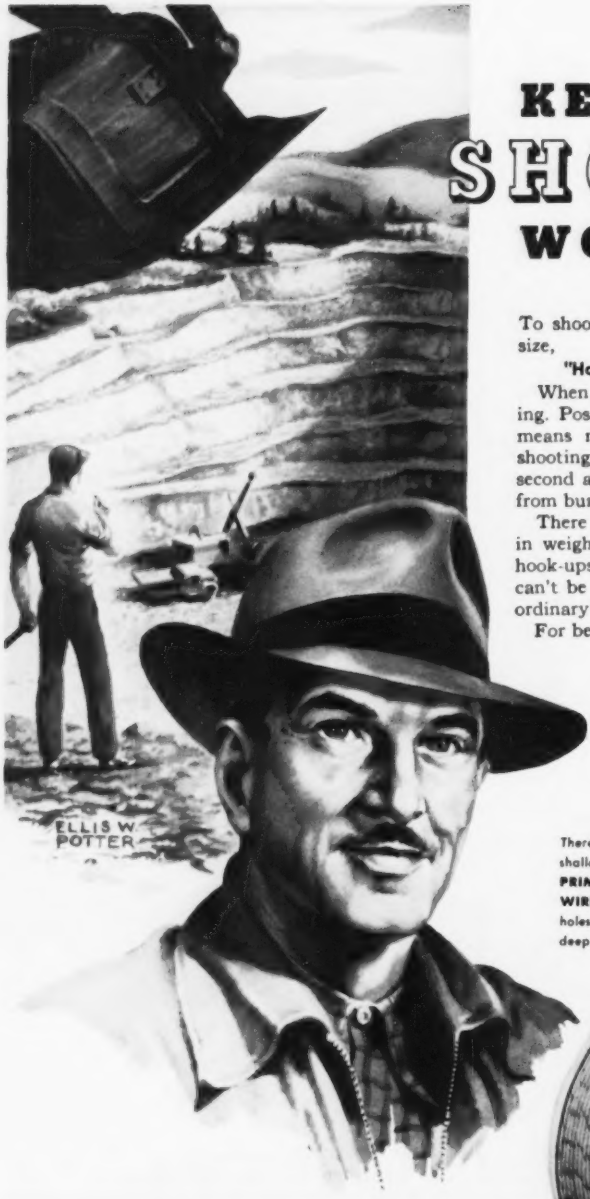
* * *

An unusual example of controlled blasting on a large scale in a commercial stone quarry is presented in the article on page 156, "Three-In-One Tunnel Blast in a Wisconsin Quarry," by John C. Richards, Jr.

The article describes the loading of 79,000 lbs. of Hercomite* X and Gelamite* D dynamite into 18 pockets in three tunnels in Dresser Trap Rock Company's quarry at Dresser, Wisconsin. The dynamite charges, primed with Primacord and electric blasting caps, were fired at one time. The resulting blast produced a sloping bank of broken stone estimated at 325,000 tons.

Before the blast was fired, news of it created a great deal of interest—it was publicized over the Twin Cities' radio stations and televised by a station in Minneapolis.

*Reg. U. S. Pat. Off.



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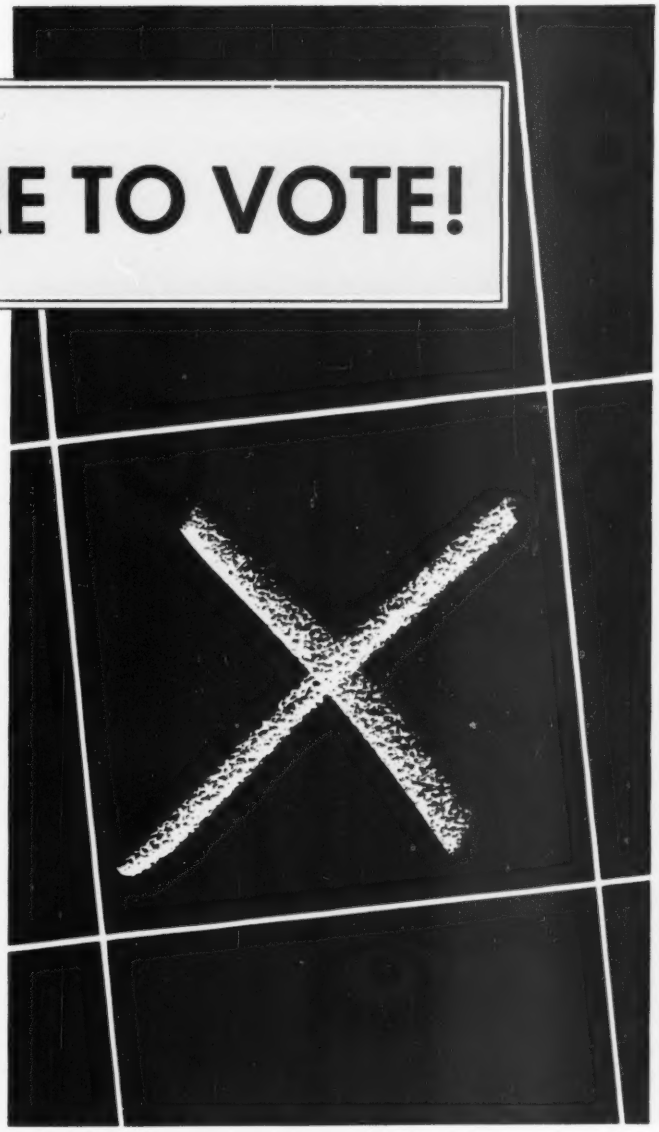

PROBLEM . . .

. . . only *one-half* of all American citizens eligible to vote in the 1948 presidential election actually went to the polls. Just 51.2 per cent, to be exact.

SOLUTION . . .

. . . good government can be won —and kept—if more voters cast ballots on Election Day. It's not merely the action of voting for a particular candidate or party. It's the principle of exercising this basic right and privilege of citizenship.

RESULT . . .

. . . you will have federal, state, and local governments that truly represent the people under our form of republic. Remember— one out of every two persons failed to vote in the last national election. Let's not make that mistake this November.

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George Floyd Ferris

VICE PRESIDENT AND GENERAL MANAGER

RAYMOND CONCRETE PILE COMPANY

A Biography

GEORGE FLOYD FERRIS' career, from an ambitious recruit just out of college to vice president-general manager, and a director of Raymond Concrete Pile Company, is a record of energetic application to the profession he chose as his lifework.

George was born in Jacksonville, Florida, February 15, 1902, the son of Robert E. and Virginia Floyd Ferris. After completing his elementary and high-school education in Jacksonville, he went to the University of Florida and was graduated in 1924, with a B.S. degree in civil engineering. At the University, George played football and basketball on class teams for four years, and was elected to memberships in Alpha Tau Omego, national fraternity, and to Phi Kappa Phi, honorary scholastic scientific fraternity. During school vacations, he kept busy in a variety of jobs, including lineman's helper on a transmission line, instrument man with a survey crew, and as an electric furnace operator.

After graduating from the University, George went to work for the engineering firm of Carr & McFadden, as resident engineer on a real estate development program at Olympia, Florida. The following year he became associated with Butler, Barnett & Taylor, civil engineers, and was assigned to direct field activities out of their branch office in Stuart, Florida. In 1926, he accepted the position of chief engineer for Mayaca Company, a subsidiary of Phipps Corporation, which was engaged in reclaiming, irrigating, and developing 1,100 acres on the shore of Lake Okeechobee, at the head of St. Lucy Canal. After this project was completed, he was transferred to the Palm Beach Company, another subsidiary of Phipps Corporation, as chief engineer on land and building developments in and around Palm Beach. While on this assignment, he collaborated with Colonel G. A. Youngberg in preparing a report recommending repair procedures on the Florida coast, following damages suffered from a hurricane.

In 1929, he moved north to become a field engineer with Turner Construction Company on the building of the Delaware & Lackawanna Terminal. He continued his association with the Turner Company for ten years, as assistant superintendent and, later, superintendent on major construction projects in the New York metropolitan area, in Illinois, and in Maryland.

Several months before the attack on Pearl Harbor, the United States Navy awarded a contract to Contractors, Pacific Naval Air Bases, a group of eight companies in a joint construction venture. The contract involved the building of airfields and numerous Naval installations extending from California to the Philippines, estimated to cost more than $320,000,000. It was the largest single construction contract ever awarded by the United States Government. The officers of the eight companies chose George Ferris to be chairman of their operating committee, directly responsible for the field organization and for the progress of work on all of the projects spread out over the Pacific Ocean, on the islands of Hawaii, Johnston, Palmyra, Samoa, Midway, Wake, Guam, and the Philippines. Upon completion of construction activities, which extended over a period of four and a half years, the project was hailed as one of the outstanding accomplishments of the war construction program. In recognition of the brilliant execution of his responsibilities, the United States Navy presented its highest civilian award, the Distinguished Public Service Award, to Mr. Ferris.

Upon his return from Pearl Harbor in 1944, Mr. Ferris was made general manager of a joint venture contract with the Navy's Bureau of Yards & Docks, for purchasing, warehousing, and shipping materials required by the Bureau throughout the world. This procurement service at its peak reached an average volume of $3,000,000 worth of material a day. While on this assignment, he was elected a vice president and director of Turner Construction Company. One year later, he resigned from his posts with the Turner Company to accept the positions of vice president-general manager, and a director of Raymond Concrete Pile Company, in which capacities he is serving at present.

George Floyd Ferris married Barbara Evans on March 20, 1942, in Honolulu, Hawaii. Mr. Ferris is the father of two daughters, Carole D. and Mary Jane Ferris. The family home is at 1125 Park Avenue, New York City.

George Ferris is a member of the American Society of Civil Engineers and of the Board of Governors, New York Building Congress. His clubs include University, Railroad - Machinery, and The Moles (vice president), in New York City; and Sleepy Hollow Country in Scarborough, Westchester County, New York.

Like many top-flight executives, his business is his hobby, but he does find time to do a little fishing or get in an occasional game of golf.

GEORGE FLOYD FERRIS

Editorial

Coal Preparation Begins at the Face

Progress in the preparation of coal has been rapid in recent years. Widespread mechanization of underground workings has facilitated loading operations. Up-to-date cleaning plants on the surface have contributed to increases in tonnage output and improved products. Programs of preparation should embrace these modern features.

It is well to keep in mind that preparation begins at the coal face—with the explosives and the blasting methods used to bring down the coal. If the coal is not blasted properly in the first place, expensive preparation and loading equipment cannot completely offset the marketing disadvantages.

Modern permissible explosives, with their lump-producing action and added safety features, have proved to be valuable aids in the initial preparation of coal in many mines. The progress made in their development and scientific application merits the attention of coal mine operators, large and small. Since explosives constitute an important item of expense in the underground mining of coal, every analysis of operating costs should include careful consideration as to their selection and use.

Periodic investigations of explosives and blasting procedures, supplemented by consultations with technically trained representatives of explosives manufacturers, will help to keep operators abreast of the times. Such a program will also be helpful in realizing more fully on mechanical investments.

Metal and Nonmetallic Mineral Mining Convention in Denver

Mining men from every section of the Western Hemisphere met in Denver, September 22 through 25, to attend the 1952 Metal and Nonmetallic Mineral Mining Convention and Exposition of the American Mining Congress. Activities centered in Denver's recently completed City Auditorium. The program provided for the coverage of all phases of the mineral industry—from prospecting through production—as well as the critical examination of economic and legislative problems. Addresses and discussions were participated in by prominent members of both Houses of the Congress of the United States and by leaders in industry.

More than 140 exhibitors occupied over 57,000 square feet of space inside and outside of the Auditorium's Exhibition Hall for the display of the latest machinery, tools, and supplies for mining, milling, and ore processing. The exhibits included equipment for exploration, rock drilling, blasting, transportation, and for each of the specialized operations for the production and treatment of ores and nonmetallic minerals. Technical representatives of the manufacturers were on hand and discussed with operating men the application of their products to modern mining and processing.

The 1952 convention and exposition at Denver provided an exceptional opportunity to mining men to obtain first-hand knowledge of the course that future production procedures are likely to follow.

Construction at Record Levels

The Associated General Contractors of America recently reported that the volume of construction in 1951 totaled $40 billion, exceeding the total value of agricultural production, normally the greatest industry in production money value in the nation. The report indicated that if materials are available during the remainder of this year, a new annual record of more than $40 billion in construction will be established in 1952.

Despite the delays enforced by the steel strike and the added time needed to get the supply pipe lines filled again, there is no evidence of a slowdown in construction volume in the near future.

Dr. John J. Rutledge 1870-1952

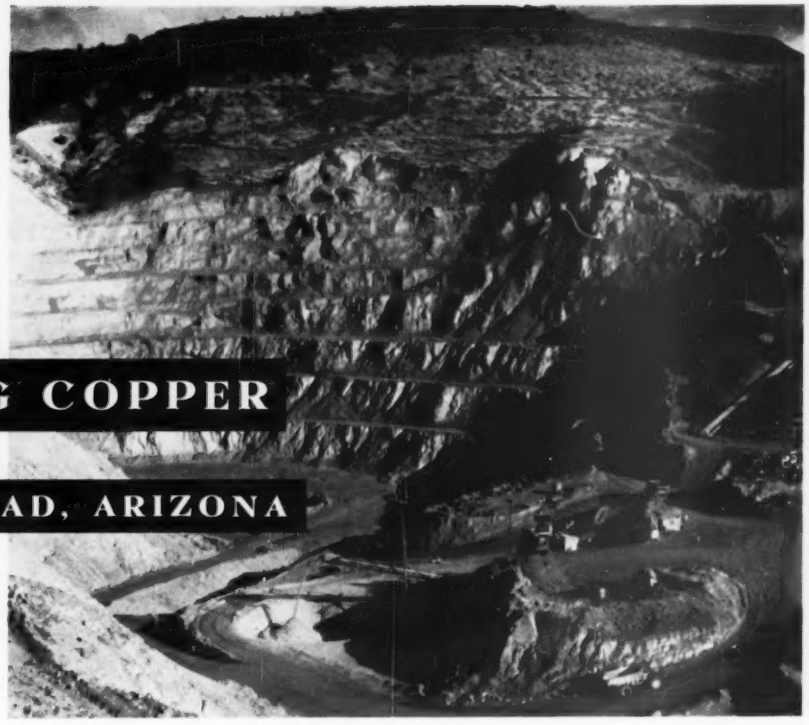
Dr. John J. Rutledge will long be remembered for his activities as a practical expert in both coal mining and metal mining, and as a geologist, a consultant, and as a mining correspondent.

During the past 23 years, THE EXPLOSIVES ENGINEER was privileged to publish a series of articles by Dr. Rutledge, based on his diversified experiences in underground mine properties, with particular emphasis on the development of mine foremen. The articles created such widespread interest that they were reprinted in booklet form to supply the demands for copies from coal mining companies and from technical schools and colleges in this country and in some foreign lands.

His unique style of weaving practical experiences into the thread of what might be called teaching was accepted with great enthusiasm by both young and old. He could always rely on his own background to authenticate his thesis.

Dr. Rutledge's many years of devoted and conscientious service to the United States Bureau of Mines, and, later, to the Maryland Bureau of Mines, won for him recognition as a public official of great stature and of the highest ethical standards.

Dr. John J. Rutledge was an outstanding executive who combined extensive experience with unusual resourcefulness to meet modern conditions. THE EXPLOSIVES ENGINEER joins with the mining world in mourning his death and in saluting the memory of a well-loved individual and an eminent mining authority.



THE BAGDAD MINE: A view of Bagdad's open-pit mine looking toward the east. Present pit production averages 3,700 tons of ore and 4,500 cu. yds. of waste material each day. Most of the haulage grades are maintained at a maximum of 12 per cent.

MINING COPPER AT BAGDAD, ARIZONA

Open-pit operations of Bagdad Copper Corporation produce an average of 3,700 tons of ore a day with a mill output of approximately 3,800 tons

OLAF HONDRUM*

THE mining and milling operations of Bagdad Copper Corporation are located near the town of Bagdad in west central Arizona, 70 miles west of Prescott. The nearest railroad is at Hillside, approximately 26 miles east of Bagdad. The Hillside station is on a branch line of the Sante Fe Railroad extending from Ash Fork to Phoenix.

The Bagdad mine has been operated intermittently for many years, with production on a modest scale. A small flotation mill was built, mine development work was carried on, and some ore was mined. About 30 years ago, an extensive churn-drill program of exploration resulted in the development of a considerable deposit of low-grade copper ore adjacent to the rather small ore bodies known at that time. Also, extensive metallurgical experiments were conducted to devise methods for treating the oxide portions of a predominantly sulfide copper ore.

With the entry of the United States into World War II, it was apparent very quickly that copper was one of the metals desperately needed and that increased production of copper from mines capable of expansion was essential. The Bagdad mine was in this category. Following the successful negotiation of a loan from the Reconstruction Finance Corporation, construction of a 2,500-ton-a-day flotation mill was begun. Also, a new mine shaft was sunk, haulage drifts were driven, and the development work necessary to provide the mill with the required amount of ore was done. Plans for the expansion program called for the ore to be mined by the block-caving method which has been, and is still being, used extensively in Arizona. The flotation mill was completed in the early part of 1943. By that time, stoping blocks had been undercut and operations in the mine were expanded.

*Mine Superintendent
Bagdad Copper Corporation
Bagdad, Arizona

From Underground to Open-Pit

In 1944, J. C. Lincoln was elected president of the corporation. He appointed Ernest R. Dickie as general manager and the latter assumed his new duties on September 1. Mr. Dickie had been associated previously with Mr. Lincoln at the Vulture mine near Wickenburg, Arizona. After thorough

A PRIMARY BLAST: The camera caught this action blast of 30,000 lbs. of Hercules 30% Extra Dynamite primed with plastic Primacord on one of the operating levels in the Bagdad pit in Arizona.

AFTER THE BLAST: In the ore formation an explosives loading ratio of approximately 1 lb. of dynamite per 1 cu. yd. of burden produces excellent fragmentation.

inspections and studies of conditions at the mine, Mr. Dickie decided that Bagdad could be worked to better advantage as an open-pit. By the spring of 1945, preparations were under way for changing over from underground mining to open-pit operations.

The change had to be made in such a way as not to interfere with the operation of the mill which was producing badly needed copper concentrates. At first, production of ore by the open-pit method was small and most of the ore mined was obtained from the underground operation. Activities in the pit were stepped up gradually, a crusher was installed, and a belt conveyor 990 ft. long was constructed to carry the ore from the crusher to the

mill. By the end of 1947, the pit was in full-scale operation and underground operations were discontinued.

Production at Bagdad increased slowly as more equipment became available. At present, the average pit production each day is 3,700 tons of ore and 4,500 cu. yds. of waste material. Approximately 80 men are employed in the pit on a working cycle of two shifts a day, six days a week. This number of workmen in the pit does not include the mechanical crew.

Equipment

The drilling equipment consists of four Bucyrus-Erie gasoline-driven churn drills—two Model 22-T's and two Model 27-T's. All of the drills are equipped with 7-in. bits. The working benches in the pit are 50 ft. high, and drill holes are drilled to bottom at 5 ft. below grade.

The excavating units include three power shovels—a 4-cu. yd. P&H 1400 electric, a 3-cu. yd. P&H 1055 electric, and a 2½-cu. yd. Northwest Diesel. Currently, only the 1055 Diesel is being worked in ore while the other two are used in stripping operations.

The hauling equipment consists of two Model 40 Tournarockers with Model A Tournapulls, four Dart 140 Torque Converter trucks, six Euclid 15 TD trucks, and four Euclid 54 TD trucks. Each of the Tournarockers has a capacity of 36 tons. The Euclids and the Darts carry 22 to 25-ton loads.

Blasting

In making primary blasts, the drill holes are loaded with Hercules* 30% Extra Dynamite in 5½ in. by 25-lb. cartridges. The cartridges, made of manila and asphalt paper, are tapered at one end to minimize the possibility of their "hanging up" in ragged holes. A handle of plastic tape is attached to the opposite ends of the cartridges to facilitate lowering them down the holes. Locally, the dynamite-loading crews refer to the tapered cartridges as bombs and think of them in terms of bombs per drill hole.

*Reg. U. S. Pat. Off.

TYPICAL FORMATION: The final cut through a bank of blasted rock is in progress with a P&H electric shovel loading into one of the company trucks. Working benches in the pit are maintained at an average height of 50 ft.

The dynamite charge in each hole is primed with plastic Primacord attached to the cartridge that is loaded in the bottom. Each loaded hole is stemmed with material from the waste benches. An effort is made to use the finest material available for stemming. At best, it is rather coarse with sharp angular fragments and, when loading it in a hole, extra precautions are taken to avoid damaging the line of plastic Primacord. Plastic Primacord has greater abrasive and tensile strength than the other grades and is much more satisfactory to use under such conditions. In preparing to blast, the ends of the plastic Primacord protruding from the loaded holes are connected to a trunk line of conventional Primacord. A blast is fired by means of a blasting cap and safety fuse attached to both ends of the trunk line.

The number of drill holes in a blast varies greatly, being dependent upon the location of a working bench and the amount of space available for drilling. Usually, two rows of holes are utilized, but three rows are not exceptional. In ore, a typical blast involves from 10 to 16 holes. In the waste material, blasts are considerably larger, comprising 20 to 30 holes. In October, 1951, 150 holes were fired in a blast, the largest to date at Bagdad. It consisted of seven rows of holes on a

(Continued on page 160)

OPERATING DIRECTORS: Bagdad's operating staff includes, left to right, George Green, mill superintendent; Olaf Hondrum, mine superintendent; George W. Colville, chief engineer; Ernest R. Dickie, the organization's treasurer and general manager.

RELOCATING A
MOUNTAIN HIGHWAY
IN NORTH CAROLINA

The W. E. Graham and Sons contract for grading and draining a right-of-way through finger ridges and over deep ravines involved the excavation of 3,000,000 cu. yds. of earth and rock

OSCAR M. DAVIS*

An 8-mile section of U. S. Highway 70 in western North Carolina, between the towns of Old Fort and Ridgecrest, in McDowell and Buncombe Counties, winds its way up steep grades in a long series of sharp curves, hairpin turns, and switchbacks on the side of the Blue Ridge Mountains. It was constructed in the early 1920's when equipment for road building was extremely limited as to type, size, and maneuverability—holes for blasting the rock were made by one man holding a piece of drill steel while another man hammered it down into the rock formation. Operating under such conditions, it was necessary that this section of the highway be located so that all phases of grading work be minimized as much as possible. As a result, the existing highway climbs up steep grades in corkscrew fashion, with shoulders inadequate for modern motor-vehicle travel. It has been classified by state engineers as among the eight worst highway sections in North Carolina. Plans for relocating it have been in the making for some time.

Project No. 8521

On August 28, 1951, the North Carolina State Highway and Public Works Commission received and opened public bids on a construction job designated Project No. 8521, calling for the grading and draining of

PRIMARY BLASTING: Excellent fragmentation resulted from primary blasts of 400 holes in 20 rows, 20 holes to a row, loaded with Gelamite 2, primed with Hercules Electric Blasting Caps.

*Hercules Powder Company
Birmingham, Alabama

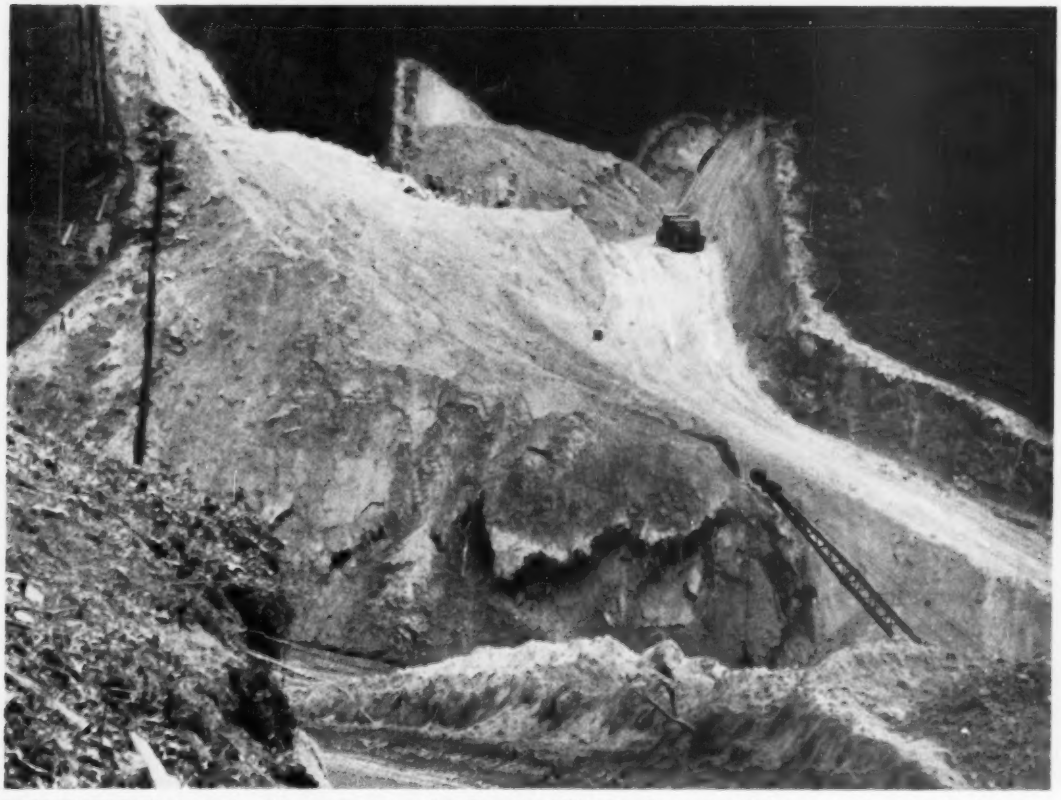
AFTER THE BLAST: When the dust cleared, a Northwest shovel operator went to work in the bank of broken rock to excavate and load it into a fleet of 15-cu. yd. Euclid trucks.

SLOPING ROCK WALLS: After a passageway 100 ft. deep had been drilled and blasted through this rock section, the walls of the embankment sloped on a ratio of $\frac{1}{4}$ to 1.

MOUNTAINS OF EARTH. Skilled operators of heavy D-8 dozers equipped with U blades pushed thousands of yards of earth down steep slopes—the one above slopes at an angle of 38 degrees.

CUT AND FILL. This view is typical of many big fill assignments on the job, referred to by the contractor as hauling off the top and filling in the bottom. The completed embankment at this location required 225,000 cu. yds. of fill.

END-DUMPING: The steep slopes eliminated the placing of fill by the usual methods. State authorities modified the project specifications to permit the contractor to end-dump fill material.



RUGGED TERRAIN: At the time this photograph was taken (December, 1951) all grading work at this location had been done by the employment of D-8 Caterpillar dozers exclusively.

DRAINAGE PROBLEMS: More than 2 miles of various sizes of pipe were laid in trenches under fills of unprecedented heights. Many difficult engineering problems were solved by the development of special construction methods.

6.15 miles of rough, tough terrain across the mountains to relocate and modernize this 8-mile section of Highway U. S. 70 between Old Fort and Ridgecrest. The project specifications included clearing and grubbing of 101 acres of right-of-way; excavating approximately 3,000,000 cu. yds. of unclassified earth and rock; and excavating 12,000 cu. yds of drainage ditches for the laying of various sizes of pipe. Time limit for completing the project was 480 working days. The general contracting firm of W. E. Graham and Sons of Cleveland, North Carolina, submitted the low bid of $2,301,093.20, and, in due course, the contract was awarded to the low bidder.

The first order of business for the contractor was clearing timber and heavy overgrowth from the right-of-way. The only way that workmen could gain access to the interior of this rough country and reach the job site was by foot. Consequently, the business of felling trees, cutting heavy overgrowth, and removing debris had to be done by men with axes, crosscut saws, light power saws, and log hooks—tools that they could carry and use on a job at such a location. The crews cut and slashed their way to a width of 150 ft. along the right-of-way. When the relocated highway is completed, there will be approximately 110 acres of timber land cleared.

Grading Operations

When the work of clearing and grubbing had progressed sufficiently so that heavy equipment could be brought into the area, the contractor moved in big units and grading operations were begun. The right-of-way for the new road cuts through and fills in a great number of finger ridges and deep ravines. In the cut sections, the width is 76 ft. from ditch to ditch; in the fill sections, 68 ft. from shoulder to shoulder. The largest cut required the excavation of 300,000 cu. yds. of rock and earth within 500 lin. ft. of roadway—one cut was made through a section 190 ft. high. The largest fill called for approximately 725,000 cu. yds. of material; the height of fill at one location was 220 ft.

Many of the slopes from the bottom of ravines to the top of adjoining ridges were too steep to permit shovel operations. In such instances an operator started a large bulldozer at the

bottom of a ridge and worked a passageway to the top, making a temporary fill. At the same time, the ridge was lowered so that a grade was made sufficiently flat for a power shovel—with the help of two bulldozers, one pulling and one pushing—to get to a working point. The State authorities, realizing the impracticability of constructing fills on this job in the usual way (horizontal layers 6 in. deep and rolled with a sheep's-foot roller), modified the specifications to permit the Graham Company to construct the fills by end-dumping. This method authorized the starting of a fill at grade point and continuing across a ravine, pushing the grade ahead. When the slope of the ground permitted, benching of the original ground was required.

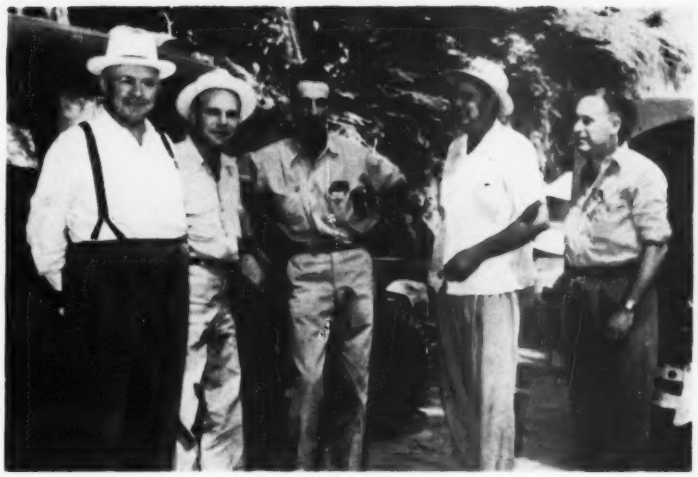
The total excavation of approximately 3,000,000 cu. yds. of material comprised 2,000,000 cu. yds. of earth and conglomerate and 1,000,000 cu. yds. of rock. It ranks as one of the biggest earth-moving jobs ever attempted in the eastern part of the United States.

Primary Blasting

For the most part, the rock encountered was a decomposed, stratified gneiss comprising irregular layers of granite, sandstone, and shale occurring in flat, folding seams. Some of the cuts through this rock formation were 100 ft. deep. Vertical holes for blasting were put down by a battery of five Ingersoll-Rand FM wagon drills equipped with 1-R and Timken detachable bits. The drills were powered by Gardner-Denver and Ingersoll-Rand portable compressors. A typical primary blast included 400 holes comprising 20 rows of holes, 20 holes in a row, each hole 2¼ in. in diameter, 18 ft. deep, spaced on 5-ft. centers. The explosives charge loaded into each drill hole averaged 12½ lbs. of Gelamite* 2 in 1½ by 8-in. cartridges.

(Continued on page 162)

*Reg. U. S. Pat. Off.



LEFT TO RIGHT: W. E. Graham, senior partner, his son and a partner, John H. Graham, project manager, and W. B. Hollen, superintendent, W. E. Graham and Sons; J. E. Terrell, resident engineer, and G. G. Page, construction engineer, North Carolina State Highway and Public Works Commission.

DEEP CUTS IN HARD ROCK: In bringing the new roadway down to grade, Graham Company crews had to drill and blast deep cuts through high ridges of hard rock in 20-ft. benches—the final depth of the cut above was 131 ft. Most of the rock encountered was a decomposed, stratified gneiss formation comprising granite, sandstone, and shale, occurring in flat folding seams. The rock blasted and excavated on the job totaled approximately 1,000,000 cu. yds.

Geofragmental Mining Methods In Underground Properties

The determination of an effective, economical solution to the problem of depth is among the most pressing problems facing the underground mining industry today

PHILIP B. BUCKY*

EXPERIENCE and history indicate that in the future a greater portion of our workable ore bodies will be at increasing depths, because the earth's surface is becoming increasingly valuable for living space and for agricultural purposes, and the amount of mineral available for each individual is becoming proportionately less in the light of man's greater demands.

It becomes important for those concerned with underground mining to find ways and means of mining or extracting minerals from the earth's crust, which will have the objectives listed below:

1. To increase the depths at which mining may be carried on.
2. To provide for the conservation of our mineral resources by increasing the percentage extraction for each ore body mined, and by mining in such a manner as to result in no harmful effects to the other ore bodies contained in the geologic structure.
3. To provide for minimum stress and deformation effects on the surface and on any structure located thereon.

Effect of Depth

As mining depths increase, the load supported by pillars of ore increases. Consequently, a greater portion of the ore body must be left to support workings while men are there engaged. Artificial support in the form of fill, timber, steel, etc., is insufficient in many cases, in others, uneconomical. Sometimes it is sheer waste because it is ineffectual. In addition, at great depths we are presented with the rock-burst problem wherein the rock in pillars bursts with explosive force because of the great loads thereon, often with disastrous effects to men, equipment, and workings. The determination of an effective, economical solution to this problem of depth is among the most pressing problems facing the underground mining industry today.

As previously indicated, the greater the mine depth, the more pillars of ore must be left to support shafts, working places, and conveyance openings. Therefore, at great depths the percentage of ore body extraction is lowered, and considerable expenditures are incurred for additional support, for accident and rock-burst insurance, and for labor. Where such dangers exist, men are loath to work except at a premium wage.

Failures in pillars and roof result in distortion and deformation of the rest of the geologic structure, with bad effects on the other ore bodies contained therein, which increase the difficulty of mining and decrease the percentage of extraction that may be expected from virgin ore bodies.

Surface Effects

In highly industrialized and agricultural areas, the mining of ore bodies at great or shallow depths results in disturbing effects on surface topography, thereby affecting surface structures and agriculture. The highly industrialized Pennsylvania coal regions at Scranton and Wilkes-Barre are illustrative of this. Surface effects may be minimized by poor conservation practices, for example, by leaving most of the ore underground for support, or by using expensive support methods such as fill or artificial support.

To help overcome the difficulties in today's mining methods and procedures, the geofragmental mining, support, and control methods are presented with illustrations.

Geofragmental Methods

The basis for geofragmental methods may be stated as follows:

A given weight of material in the solid state, W, has a volume, V, and various strengths and moduli.

When this material is fragmented by explosives, crushing, or by other means, its weight, W, remains the same, but its volume, V, increases to an amount equal to 1½ V±. The compressive strength of the material, when confined, approaches that of the solid.

It may be reasoned, therefore, that if an opening is made underground, and the material above, below, or to

*Professor of Mining,
Executive Officer, School of Mines
Columbia University, New York, N. Y.

the sides of this opening for a sufficient amount, is fragmented, by any procedure, this fragmented material will expand in volume, exert force, and serve to: (a) control the amount the overlying material may subside; (b) be sufficient to completely support the overlying material; (c) be sufficient to exert force, or lift, on the material overlying it, and side pressures on the material alongside and cause the material to move.

Since the volume, and therefore the force exerted by a given weight of confined solids, increases as the particles or fragments become equal or uniform in size, the introduction of explosives (liquid variety) into a confined mass of fragments may serve to produce a uniformity in size which will have the effect of increasing the forces exerted.

The geofragmental procedure may be explained further as follows: If it is assumed that a mined-out opening 6 ft. high is available, and that the fragmented material in the roof or bottom increases one-half in volume, then if holes are drilled and blasted and break down 12 ft. of roof or bottom rock, the increased volume will be 18 ft. The room then will be completely filled with 18 ft. of broken rock, having the supporting power of the broken rock, but exerting no upward pressure on the geologic section.

However, if the drill holes are of sufficient length to blast more than 12 ft. of roof or bottom rock, then a pressure will be exerted against the geologic section of an amount which may be determined by experiment. The fragmentation of such a quantity may result in an upward movement of the overlying material, a sidewise movement of the solid ribs, or both.

From the preceding, it may be reasoned that geofragmental methods provide economical procedures for using the material in the earth's crust to accomplish: (a) an increase in the depths at which workings may be carried on by providing a means for relieving mine pillars of load and stress. This is a proposed solution to the rockburst problem—a solution much sought after at present; (b) an increase in the percentage of extraction from all ore bodies. It follows that the economical support methods presented here reduce the ore pillar requirements; (c) conservation of the remainder of the geologic structure and the minerals contained therein for future use and economical extraction by providing for the support necessary to minimize deformation and stress; (d) minimizing or preventing surface subsidence and surface structural failures by providing the necessary support. It serves as a conservation and economical measure in making available minerals where population is dense; (e) control of the deformation of solution bearing overlying beds so as not to endanger present or future mine workings from inflows of any liquid.

Application Procedures

Long- and short-face mining in relatively thin and flat or slightly inclined deposits:

The method is illustrated in Figure 1, a plan view, and in Figure 2, a section. Main entries, 1, pillars, 2, and crosscuts and stoppings, 3, are constructed in any number as required by law. They are shown with two main entries serving the area above and a similar number serving the area below.

Cross entries, 4, with their pillars, crosscuts, and stoppings, serve to delineate a panel or section, and the length of working face, 5. There is nothing prescribed about the number of main and cross entries to be used; they may be increased or decreased. As shown, they are familiar to coal mining operators.

The working procedure is as follows:

1. The working face, 5, is established adjacent to the entry protection pillar, 8, and is to advance upward. Advances, 6, and crosscuts and stoppings, 7, are established, providing for the free movement of air and materials along the working face, 5. The air is shown by arrows as travel-

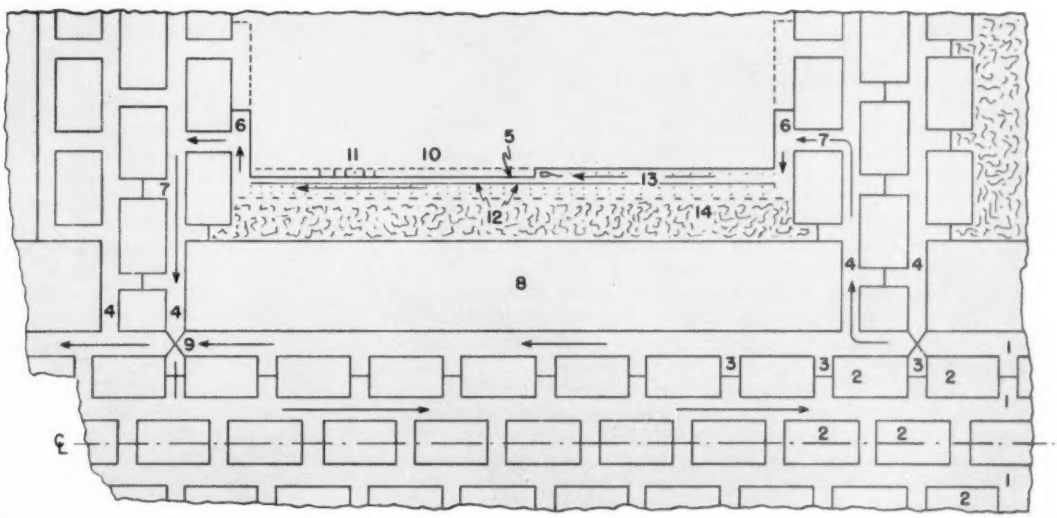


Figure 1: This plan view shows application procedures in long- and short-face mining in relatively thin and flat or slightly inclined deposits.

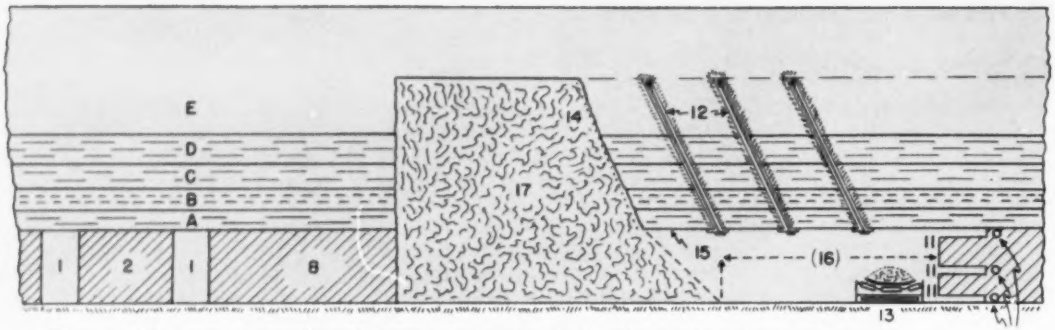


Figure 2. This section view supplements Figure 1, on page 153. The number of main and cross entries used may be increased or decreased.

ing from right to left, from the mains, through the inby cross entries, 4, then through crosscut, 7, along working face, then through the outby cross entry, 4, the overcast, 9, and into the return main entry.

2. An undercut may or may not be made along Face 5. The use of an undercut depends on the material mined, the state law, and the demands of the inspection service. It is not shown here. The ore or coal face, 5, may be drilled for blasting with long holes, 10, parallel to the face, or short holes, 11, perpendicular to the face.
3. Long-hole drilling and blasting, 10, will result in the complete length of face being blasted for the full advance. Short-hole drilling and blasting, 11, permits blasting of sections along the face of any desired length.
4. After blasting, the loading machine is moved in and loads the material onto a conveying unit—onto a belt or into cars—13. It may be assumed that the loading machine travels from right to left and that the conveying unit, or ore, travels from left to right.
5. Support for the roof is provided by props or roof bolts at positions 12, Figures 1 and 2. The preferred support method is accomplished with recoverable roof bolts as shown, because the roof bolt holes, 14, may be used as roof blast holes. The support work follows closely the work of the loading machine to minimize the length of time a roof portion is unsupported.
6. As the placing of new support near the working face, 5, takes place, the withdrawal of the recoverable roof support at Line 15 is taking place. These holes are then loaded with explosives for fragmenting the roof.
7. The roof is then blasted and the roof material is fragmented to provide support to the overlying structure and to assume a position as shown in Figure 2.
8. Complementary work, such as the moving of the conveyor and the track, the erection of stoppings, the driving of advances, and the advancing of power lines, takes place at convenient times, after which the cycle is resumed with Item 1. Here the work is shown as being carried on, on the advance. On the retreat, all pillars, including those in the cross entries, may be removed with or without geofragmentation procedures. In this case, the dimensions of Pillars 2 and 8 may be relatively small, for the loads they support are quite small.

The method illustrated considered a Barodynamic condition where the immediate roof consists of a series of thin beds requiring considerable support to provide a sufficient span, 16, Figure 2, between the working face and the fragmented material for the free movement of men and equipment.

With a Barodynamic structure consisting of thick, strong, and overlying beds which will allow for a sufficient span, 16, roof bolts may not be necessary. It may, under certain conditions, be more desirable to drill and blast down holes in the bottom rock to secure the necessary volume of geofragmental material for support.

The proper geofragmental procedure and the dimensions used will, in any case, depend on a Barodynamic study of the structure and experiment to determine the constants for the fragmented material.

The method described has the following advantages:

1. A concentrated area from which a high tonnage may be maintained.
2. The cross entries, 4, may be sufficient in number, or extended for sufficient lengths, to provide storage, shop, office, repair, and the other necessary facilities close to the point of production.
3. The length of face may be geared to the capacity of the equipment. For example, a loading machine with a 1,500-ton capacity per working shift will have a face length, dependent on the height of ore and depth of cut, sufficient to provide 1,500 tons.
4. An orderly factory system sequence may be employed such as ore or coal loading and conveying, followed by roof bolt drilling and placing, ore or coal face drilling, conveying equipment moving, removal of roof bolts, and the loading and shooting of the required drill holes to provide both geofragmental support, and ore or coal for the loading equipment.
5. The method is amendable to any and all types of continuous mining machines, loaders, conveyors, and haulage units.

Rock-Burst Control

The application of geofragmental methods for the control and relief of rock-bursts is illustrated as follows:

Figure 3 shows a geologic structure amendable to rock-bursts. The depth from the surface is great. The beds, 2, 3, and 4, are of considerable thickness and strength and will support themselves over large spans with mini-

mum deformation. The ore body material in Pillars 5, 6, 7, 8, and 9 is strong and exhibits bursting tendencies. If L is the distance between pillar centers and Ps is the weight per unit of material to the surface, then the pillar loads = Ps x L. If PsL is of a sufficient amount, the pillar will burst.

By drilling and blasting fragmentation holes, 10, in the bottom between pillars for a vertical distance greater than twice the height of the ore body, the bottom rock fragmented will increase in volume to such an extent as to exert forces, 11, on the geologic structure above the ore body, thus relieving the pillar of part of its load and its tendency to burst.

Fill and Fragmentation

Where the ore body is thick and fill is available, the amount of drilling and fragmentation may be reduced. This is illustrated in Figure 3, between Pillars 6 and 7. The fill, 12, is placed, after which holes, 13, are drilled and blasted to fragment the roof in an amount sufficient to provide for upward pressures, 11, on the structure between Pillars 6 and 7. (See Figure 3.)

For the condition as illustrated, Pillar 6 will be safe for men in openings made therein for haulage, shops, etc. Pillar 8 will tend to burst.

As a method of preventing rock-bursts, fill is not effective in either flat or dipping deposits, where the hanging wall beds are thick and deform a small amount over large areas, thus transmitting large pillar loads, because all fill deforms with pressure. Fragmentation of the hanging or footwall rock to put the fill in a position to take loads and exert it on the fragmented rock and geologic structures is necessary to relieve pillar loads.

The application to inclined beds may be envisaged by tilting Figure 3 at an angle. As the angle becomes steep, the stress component exerting pressure on the pillar approaches the horizontal. It is normally referred to as a side pressure.

Control of Bottom Heave

Bottom heave, or the tendency of the bottom to rise in mine workings, may be considered to be due to high unit pillar loads on the mine bottom rock. These loads exert lateral forces on the bottom rock which cause the bottom rock to flow and rise in openings. The cost of maintaining openings under such conditions may be excessive. This condition may be relieved by the use of geofragmental or geofragmental and fill methods, which decrease the unit load on the pillar, and, therefore, on the bottom rock.

Geofragmental or geofragmental and fill methods may be used for:

A. Controlling the amount of geologic deformation and surface subsidence,
B. Supporting and realigning shaft areas, and
C. To provide for deformations which will re-elevate subsided surface areas.

A.—The amount of geologic and surface deformation may be controlled as follows: If in Figures 1, 2, and 3 the physical support properties of the fragmented material or fill and fragmented material were determined, then the amount necessary to provide the deformation and support requirements could be calculated.

B.—The support and realigning of shaft areas may be obtained by creating a geofragmental support area sufficiently in excess and under the area requiring support, increasing the upward forces estimated as necessary to realign at the required positions by additional geofragmentation, or increasing the uniformity of the fragment size by additional fragmentation with explosives at the position requir-

(Continued on page 161)

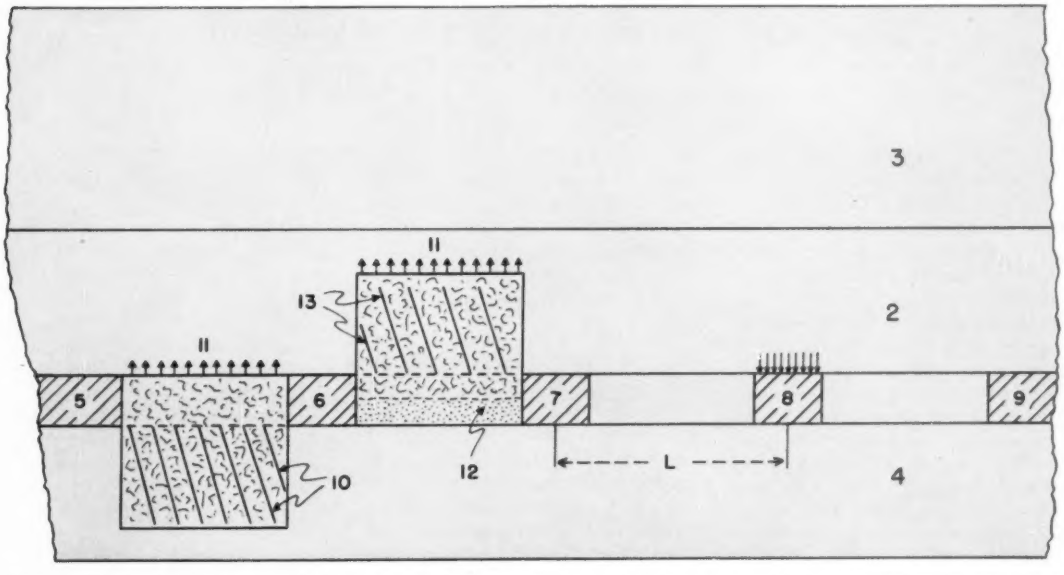


Figure 3: This drawing illustrates a geologic structure amendable to rock-bursts. The application of geofragmental methods for the control and relief of rock-bursts is indicated.

THE QUARRY FACE. The rock in the Dresser quarry face is a hard, blocky basalt formation. The height of the face over the three tunnels varied uniformly from 75 ft. at one end to 90 ft. at the opposite end. The burden of rock in place over the tunnels totaled 99,000 cu. yds.

THREE-IN-ONE

TUNNEL BLAST

IN A WISCONSIN QUARRY

Three tunnels loaded with 79,000 pounds of dynamite were fired in one blast to produce 325,000 tons of broken stone for Dresser Trap Rock Company

JOHN C. RICHARDS, JR.*

JOHN WUNDER, a pioneer in the promotion of the use of reinforced concrete in the construction of buildings and bridges, opened a quarry and built a plant at Dresser, Wisconsin, 50 miles northeast of Minneapolis, in 1914, to produce crushed stone for concrete aggregate. After his death in 1931, operations were continued by his heirs until 1949, when they decided to get out of the quarry and crushed stone business. An opportunity to purchase the property was offered to businessmen in Dresser and in nearby St. Croix Falls, Wisconsin. The offer was accepted and the local group began operations June 1, 1949, under the name of Dresser Trap Rock Company, with Jule Larson as superintendent of operating procedures. The company has been successful from the start.

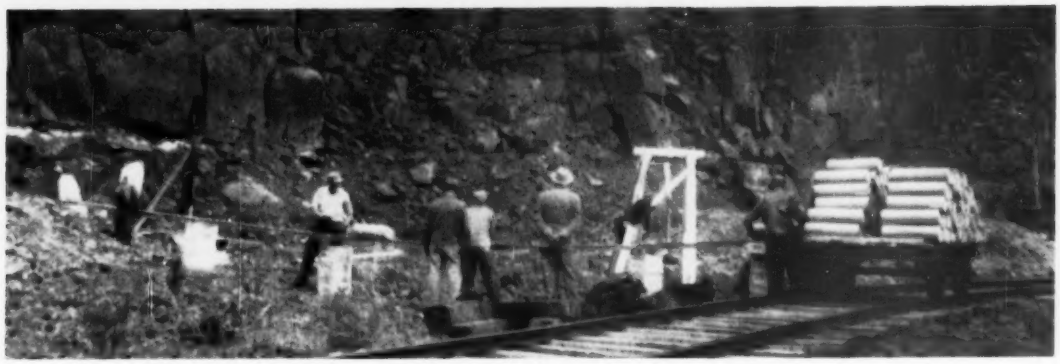
*Hercules Powder Company
Duluth 2, Minnesota

Hard, Tough Rock

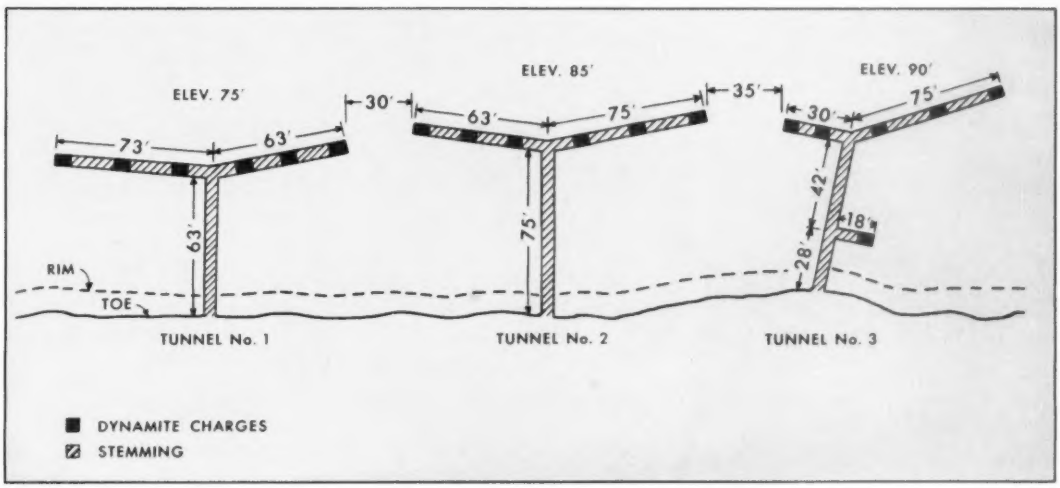
The term trap rock is a convenient field term for igneous rock, that is, rock which results from the action of intense heat, such as granite, or, as in the case of the Dresser quarry formation, basalt. Commercial crushed stone produced from the Dresser rock meets the most rigid tests for hardness, toughness, and durability. It crushes into jagged pieces, never into round pieces. For this reason, it mixes well in cement or in bituminous material. One of the company's principal outlets is to road builders who use the crushed stone for seal coating on blacktop surface work. Other uses include ballast for railroads, filter for sewage disposal plants and water supply systems, and in aggregate for heavy-duty floors.

Primary blasting in the quarry is done by the tunnel, or coyote, method. After blasting, the broken rock is excavated with power shovels and loaded into mine cars for transportation by rail to the crushing plant, a distance of about one-half mile. At the plant the broken rock is dumped from the mine cars into a 72 by 84-in. primary crusher. This primary crushing unit at Dresser was, until a few years ago, the largest of its kind in the country.

AFTER THE BLAST: The simultaneous detonation of 79,000 lbs. of Hercomite X dynamite in the three tunnels produced a sloping mound of broken rock estimated at 325,000 tons.



DYNAMITE SUPPLIES: The 50-lb. cartridges of Hercomite X, packed in 23-G containers, were transported in a railroad pushcar to the tunnel areas and relayed to the portals on an aluminum conveyor.



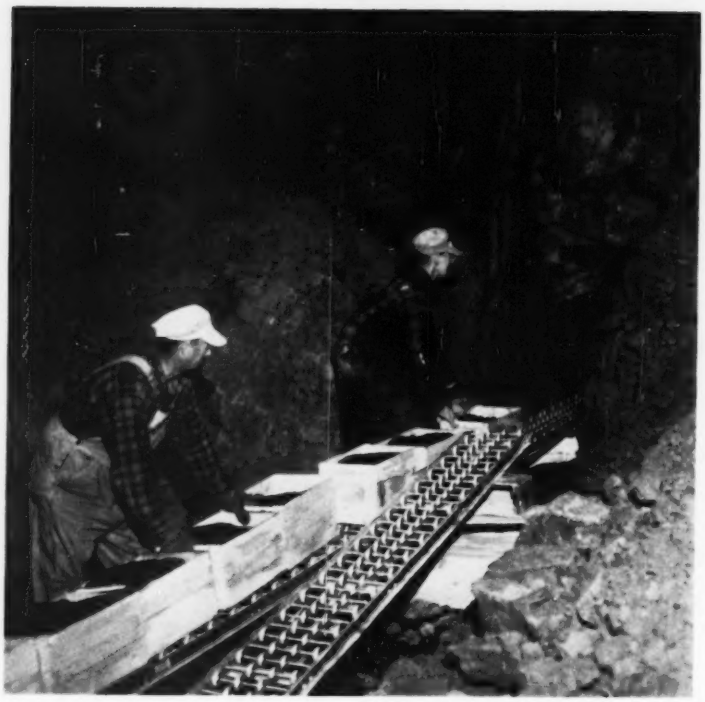
THREE-TUNNEL LAYOUT: This diagram indicates the overall layout of the three tunnels and the loading and stemming of 79,000 lbs. of dynamite in the wings, or drifts, of each tunnel.

Reports indicate that one other similar-sized crusher is now in operation.

During the late months of 1951 the company made plans to fire a blast on May 14, 1952, of three tunnels at one time in the quarry. The three tunnels were driven horizontally into the quarry face at floor level, each 70 ft. deep, 4½ ft. high, and 3 ft. wide. From the ends of these tunnels, drifts, or wings, were driven. The total length of the six wing tunnels from end to end was about 445 ft. The height of the face of rock over the tunnels varied uniformly from 75 ft. at one end to 90 ft. at the opposite end. The burden of solid rock over the three tunnels totaled 99,000 cu yds. Past experience and calculations indicated that the blast required approximately 79,000 lbs. of dynamite. It was decided to load the dynamite into 18 pockets in the six wings of the three tunnels. At each of these 18 locations where dynamite charges were to be placed, the size of the bore was deepened and widened slightly. An accompanying drawing indicates the layout of the three tunnels, the locations of the powder pockets, and the stemming.

The dynamite selected for the blast was Hercomite® X, with 100 lbs. of Gelamite® D as a primer charge in each of the 18 charges. The Hercomite X dynamite was packed in 50-lb. 23-G containers. This eliminated the necessity of opening the cases, also the disposing of the empty cases.

Reg. U. S. Pat. Off.



STEMMING OPERATIONS: Wooden boxes, each loaded with approximately 1 cu. ft. of stone screenings, were moved into the tunnels on the aluminum conveyor for use as stemming between the dynamite charges and in the stems of the tunnels.

Loading Operations

To facilitate loading the dynamite charges in the tunnels, and the stemming between the charges and out to the three portals, about 200 ft. of aluminum gravity conveyors in 10-ft. sections were used. They were light in weight and easy to handle. The dynamite containers and the boxes loaded with stemming rode easily and quickly on them, thereby considerably reducing the time usually required for such tunnel-loading activities.

The dynamite was transported from a central storage point to the area of the tunnels by means of a railroad pushcar. Upon arrival, it was assembled in separate piles in predetermined amounts corresponding to the pockets into which it was to be loaded. Stone screenings for stemming were unloaded and piled near the portals of three tunnels.

Loading operations were started on May 7 of this year and were continued for 20 hours each day, the workmen operating on two 10-hour shifts. The day shift handled the loading of the explosives and the night shift took care of stemming operations.

After the conveyors were assembled inside the tunnels and the wings, loading the dynamite into the wing ex-

CLOSE-UP: The excellent fragmentation obtained is evident in this view of the south end of the quarry soon after the three-tunnel blast had been fired.

JULE LARSON: The photographer took a picture of Dresser's Superintendent Jule Larson standing alongside a pile of Hercomite X dynamite in 23-G containers near one of the tunnel portals.

tremities was started. Two lines of Primacord, one line on each side of each wing, were brought forward in advance of the loading activities. Cross ties of Primacord were made through the Gelamite D priming charges to each of the main Primacord side lines.

Stemming the Charges

The stone screenings used as stemming material were loaded into wooden boxes and transported over the same aluminum conveyors which carried the dynamite. These boxes, containing approximately 1 cu. ft. of screenings, were handled easily by the men working inside the tunnels.

All the dynamite charges were loaded within the drifts, or wings. After the wings of the tunnels had been completely filled with stemming, Primacord cross ties were made and the main tunnels completely filled with stemming. Cross ties of Primacord were made along the stem of the main tunnels as added assurance against the possibility of one of the lines being inadvertently cut in the loading or stemming operation.

To insure intimate contact and positive Primacord connections, friction tape was used to cover each Primacord connection knot.

After the final stemming had been completed, the quarry floor area was cleared of track, electric lighting facilities, loading and hauling equipment, and debris. One main line of Primacord was strung along the quarry floor in front of the tunnels. Each branch line of Primacord from each tunnel was tied into the main line and electric blasting caps were connected at each end of the main trunk line. The leg wires of the electric blasting caps were connected in series.

An electric firing line was laid from the tunnel portals to a firing switch which was energized from a 220-volt A.C. power source.

Blast Televised

Before the blast was fired, news of it had created a lot of interest—it was publicized over the Twin Cities' radio stations. One TV station in Minneapolis secured permission from Dresser Trap Rock Company to televise the blast. Cameras equipped with telephoto lens were stationed at vantage points. A camera-equipped airplane from Station KSTP-TV circled the quarry to get pictures of the blast from the air. Because of these factors, it was necessary that the blast be fired at a specified time. To be doubly sure that the firing circuit was operative, the line was tested ahead of time. The test proved that the firing line was in proper working order, after which the final connections were made and the blast was fired on schedule.

The results from this three-tunnel blast were entirely satisfactory and excellent fragmentation was obtained. Estimates indicated that a total of about 325,000 tons of rock was broken.

DRESSER COMPANY EMPLOYES: Some of the quarry and plant employes of Dresser Trap Rock Company pose for a group picture in front of the office at Dresser, Wisconsin.

(Continued from page 145)

hillside, each row at a higher elevation than the one below. The lower three rows were drilled to the 3280 bench and the upper four rows were drilled to bottom at the 3330 bench. This blast was made so that stripping on the west side of the pit could get under way.

Varying Formations

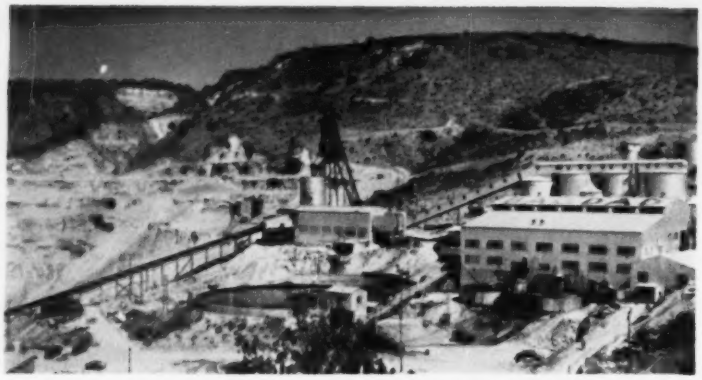
From the standpoint of blasting, the rock formations at Bagdad may be divided into three classifications: a monzonite porphyry in which the ore occurs, a leached porphyry overlying the ore, and a conglomerate on top of the other two. The spacings of drill holes and the amounts of dynamite charges are varied to fit the different types of ground.

In general, the ore formation is fairly hard and, in places, quite brittle, which retards the speed of drilling. Drill holes are spaced on 12-ft. centers and are loaded on a basis of 0.7 to 1 lb. of dynamite per 1 cu. ft. of burden in place. Excellent fragmentation is obtained from these blasts. In one section, rather limited in extent, the ore differs from the usual brittle formation and, in mining parlance, is known as "tough." In this material, the drill holes are spaced closer together, on about 9- or 10-ft. centers, and the dynamite loading factor is increased materially. Primary blasts produce a rather high percentage of large boulders which have to be reduced by secondary blasting for economical handling.

The leached porphyry formation is softer than the ore underlying it. In blasting the porphyry, the drill holes are spaced 15 to 18 ft. apart and are loaded with dynamite charges on a basis of about 0.6 lb. per cu. yd. of solid burden. The results are generally satisfactory. Certain areas in this formation tend to be blocky and some secondary blasting is required.

Most of the leached porphyry contains substantial amounts of copper in the form of oxides and carbonates and is stock-piled for leaching with acid at a future date. At present, the biggest stock pile forms a dam and tailings from the mill are disposed of behind it. Under these circumstances this stock pile serves a dual purpose.

In the conglomerate formation, the spacing of drill holes and the loading of explosives charges are about the same as in the porphyry. Most of this formation is not hard and drills easily, but it contains numerous thin layers of a hard, fine-grained material. To obtain satisfactory fragmentation from blasts, deck loading of the dynamite charges is standard procedure. The top of each dynamite charge is brought to within 18 ft. of the top of the hole, sometimes a few feet closer. This vertical spacing of the column of dynamite brings the cartridges in closer contact with the various cemented layers of the fine-grained rock, and insures better fragmentation in primary blasts with no increase in dynamite consumption.



THE MILL: The mill at Bagdad was designed originally to treat 2,500 tons of ore a day. Following the successful introduction of pit operations, an additional ball mill was installed, which increased the capacity to about 3,800 tons a day.

Haulage

The pit at Bagdad straddles Copper Creek Canyon and haulage presents more than the usual problems. The location is unfortunate in that it causes adverse grades for both ore and waste hauls. In the early days of pit operations, 16 to 18 per cent grades were common. As the pit area began to expand, a slight reduction of grades became possible. At present, most grades are held to a maximum of 12 per cent. Future operations may make further grade reductions possible, at least on some of the haulage routes.

The Mill

The mill was designed originally to treat 2,500 tons a day. Since pit operations began and ore became easier to obtain, an additional ball mill has been installed, increasing mill capacity to about 3,800 tons a day. Skilled operators keep close watch on the flotation circuits with the result that recoveries in the mill have increased greatly in the past two years. A bank of flotation cells to recover molybdenum has been added; previously, the molybdenum was lost. These improvements have been introduced through the initiative of George Green, mill superintendent.

Operations Expanded

Open-pit operations have resulted in numerous changes in and around Bagdad. The buildings of the town were located originally on the south side, and along Copper Creek. When this area was needed for stock-piling oxide material, the buildings were moved to a location 2 miles east, on the road to Hillside. During World War II, the Government built some small houses and a group of apartments on the property. Later, these sites were needed for the disposal of tailings and the buildings were moved to another location on the main road. This area is now the town of Bagdad.

The operating staff at Bagdad Copper Corporation includes Ernest R. Dickie, treasurer and general manager; James H. Cazier, general superintendent; George Green, mill superintendent; Olaf Hondrum, mine superintendent; George W. Colville, chief engineer; Edward Girard, construction superintendent; Walter D. Deacon, chief electrician; together with Maurice Thon as chief accountant.

Geofragmental Mining

(Continued from page 155)

ing increased forces for alignment.

C.—Re-elevation of the surface may be obtained by creating a geofragmental support condition under the required area, increasing the height of the geofragmental support area, or by further fragmentation of the geofragmental support to increase the uniformity of the particle sizes.

The advantages of geofragmental mining support and control methods may be listed as providing for:

1. Safety in mining.
2. The use of waste material for support purposes with a minimum of handling and cost.
3. Adaptability to modern developments, methods, and machinery.
4. The introduction of the factory system in mines, whereby production work may be concentrated in a given area and the development work kept to a minimum.
5. High rates of extraction.
6. A minimizing of disturbance to the rest of the geologic structure.
7. Control of surface subsidence.
8. A fundamentally sound method for solving the rock-burst problem.
9. An increase of the depth in the earth's crust at which mining may take place.
10. A means for minimizing and controlling bottom heave in mine workings.
11. Use in conjunction with fragmented material or fill from other sources, i.e., tailings, refuse, etc.
12. Special value in making minerals available in highly industrialized areas, in agricultural and forest areas, in areas overlain by large bodies of water such as the ocean, lakes, and rivers, and in areas overlain by fluid-carrying beds of geologic materials, as in oil or gas fields or water-bearing sandstones.

Considerable research and testing of the foregoing concepts have taken place in the Barodynamics Laboratory of the School of Mines, Columbia University, New York City. The concepts are now being field tested and patent application has been made.

BRUNNER & LAY
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For record-breaking performance . . . for ease of operation, you can't top a McCarthy Vertical Drill. Recently, on one difficult job, workers using McCarthy equipment drilled an 8-inch hole 100 feet deep in only 40 minutes! The derrick is raised and lowered by hydraulic power . . . finger tip controlled . . . and a 60 H. P. gasoline motor is part of the standard equipment.

The McCarthy Vertical Drill, manufactured by The Salem Tool Co., is adaptable to high wall and key way drilling and diamond drill boring . . . drills 90% of all limestone and sand rock formations, and readily burrows through shale. Send today for complete information, and for a free copy of The Salem Tool Company booklet.

MINING EQUIPMENT SINCE 1901

SALEM

THE SALEM TOOL COMPANY

MOUNTAIN HIGHWAY

(Continued from page 151)

primed by a Hercules* No. 6 Electric Blasting Cap. Each loaded hole was stemmed to the collar with rock dust from drill cuttings. When a blast was ready to be fired, the leg wires of the caps were connected in series parallel and detonation was accomplished by means of a conventional blasting machine. Excellent fragmentation was obtained.

Difficult Drainage Problems

Drainage on the project presented engineering problems of major importance because pipe had to be laid in culverts under fills of unprecedented heights. The specifications called for the excavation of more than 2 miles of ditches and the laying of various sizes of pipe in them to channel the freshets of the peaks. One line of 66-in. multiplate pipe of 1-, 3-, and 8-gauge metal is 576 ft long. This line is strutted with heavy timbers to prevent the pipe from being crushed by the weight of the 185-ft. earth fill above it. After this fill has had time to settle, the timbers will be removed. Other special methods of construction in connection with the laying of the pipe lines under extremely high fills were developed and approved.

The embankments along the right-of-way are sloped on a ratio of ½ to 1, with some ¼ to 1 in cut sections where the rock formations permitted. The maximum grade of the new road is 6 per cent, with a maximum curvature of 7 degrees.

Equipment

The principal equipment used by the Graham organization included five Ingersoll-Rand FM wagon drills; eight portable air compressors—five Gardner-Denvers and three Ingersoll-Rands ranging from 315 to 600-c.f.m. capacity; four Northwest power shovels with 2⅜ and 1¾-cu. yd. dippers; two Caterpillar rippers; five 12-cu. yd. Le Tourneau scrappers; sixteen tractors—fifteen Caterpillars and one International; two Caterpillar motor graders; ten 15-cu. yd. rear-dump Euclids; four 16-cu. yd. Athey crawler wagons; two Hobart electric welders; one Novo water pump; five jeeps; and a fleet of miscellaneous Ford, Chevrolet, and GMC trucks. Also, a Motorola 10-watt transmitter - receiver unit which made contact possible at all times between the contractor's field office and the automobiles of the supervisory personnel on the job.

The supervision of construction activities is under the direction of the North Carolina State Highway and Public Works Commission personnel: Henry W. Jordan, chairman; L. B. Peck, division engineer; G. G. Page, construction engineer; and J. E. Terrell, resident engineer. For the contractor, John H. Graham, a partner in the W. E. Graham and Sons firm, is project manager, assisted by Wilson B. Hollen, superintendent; Harry B. Morris, project engineer; and G. Barney Teague, foreman of drilling and blasting operations. As senior partner and administrative head of the Graham organization, W. E. Graham was a frequent visitor to the job. His broad knowledge of all phases of heavy-construction work, developed through 43 years of experience in the field, contributed very materially to successful and smooth-running operations on this contract.

More Contracts to be Let

Construction progress on Project No. 8521 is proceeding on schedule. As work on the Graham contract draws to a conclusion, additional contracts will be let by the State for placing base material and top paving for a dual-lane boulevard, each lane 22 ft. wide. The lanes will be separated by a safety strip 4 ft. wide, raised 3 in. above the grade of the two lanes. Also, a contract will be let for the building of a bridge across the Southern Railway tracks at Old Fort. When the relocated highway is completed, it will be one of the most modern and scenic stretches of roadway in the mountain regions of western North Carolina.

*Reg. U. S. Pat. Off.

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Full speed ahead is present-day demand and you can command it with a Loomis "Clipper" Blast Hole Drill.

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A HAMMER THAT BREAKETH OUR ROCK

BY CHARLES F. THOMAS*

SINCE Tubal-cain forged bright silver and bronze,
And taught fellowmen in his craft,
All mankind has sought earth's riches to reach,
With tunnel, a raise, or a shaft.
Each age found crude means to chisel and chip;
Wrought metals to fashion strange drills;
Shaped stone sledge to cob the soft, shattered seam;
Or wedged the loosed rock with deft skills.

But treasures laid deep in vaults of old earth,
Far richer than silver or gold,
Resisted weak man until powder came
With forces to break Nature's hold.
Then pick and the wedge soon gave place to drills,
And handsteel long held a great place,
As science advanced with mineral arts,
And industry strove to keep pace.

The doublejack, swung with fierce, rhythmic power,
Brought fame to "The Terrible Swedes,"
Yet miners as skilled, whose names are forgot,
Gave wealth to the world with their deeds.
But what man today, with hammer and drill,
Where skill plays a much-needed part,
Could swing on an upper, backhole, or cut,
With knack of the yesteryear's art?

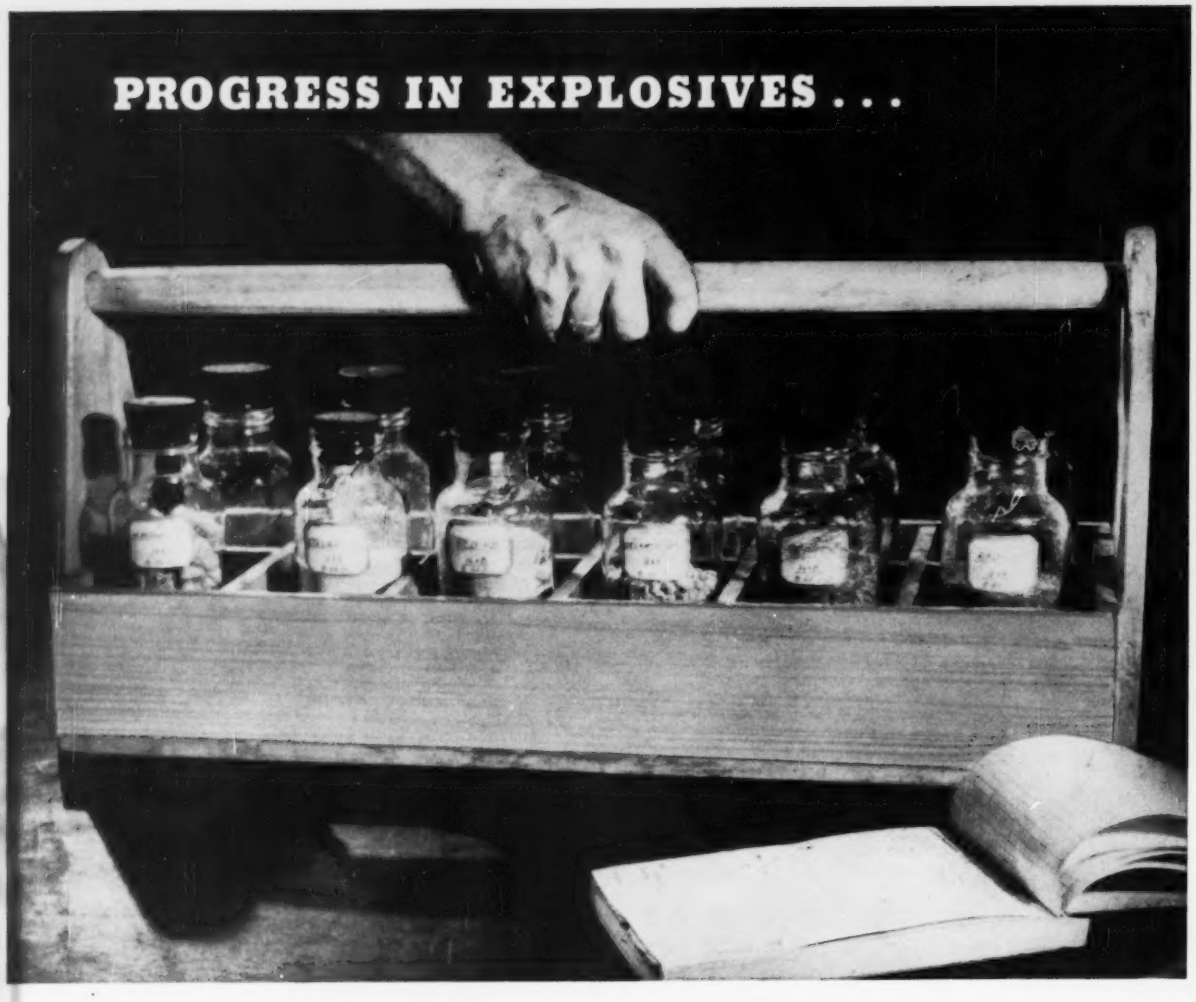
The air-driven "Slugger," long years ago,
With blows like the hammer of Thor,
Earned well its great name with hard, battling men,
Who fought in an underground war.
The hand of a master cranked down the feed
Of tough, churning bit to the face;
While chucktenders heaved on nuts with a wrench,
To keep the machine in its place.

No drill holes were cleared with water through steel,
'Til Leyner's long planning came true,
With drilling tests proved 'neath Red Mountain's peaks,
When wet Joker Tunnel holed through.
No cranking today on self-feeding drills;
No messing with squirt guns or wire;
Slip steel into chuck, loose water, and air,
And hustle like hell for your hire!

No backbreaking toil with shovels today,
For setup with column or bar;
The jumbo, fullrigged, with hose, oil, and steel,
Rolls in as men muck the last car.
With strange, gantry frame shoved tight to the face,
And drills set like guns on a ship—
Strange contrasts in mining from days long ago,
When slaves gouged a tomb with flint chip.

*P. O. Box 1017, Ephrata, Washington

PROGRESS IN EXPLOSIVES . . .



EVERY LOT TESTED

Here are some of the samples of explosives taken daily at one Hercules plant. Every day, at every plant, samples of each lot are analyzed and tested for conformity with Hercules' strict chemical and physical standards.

Sensitivity, consistency, water resistance, moisture content, density, percentages of various ingredients . . . these are some of the exacting laboratory inspection standards that must be met.

From raw materials to packaged products, Hercules' progress in explosives assures better blasting performance and helps to lower blasting costs.

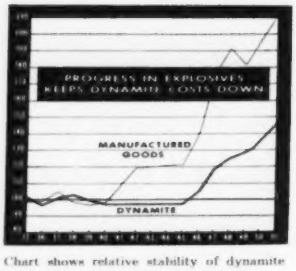
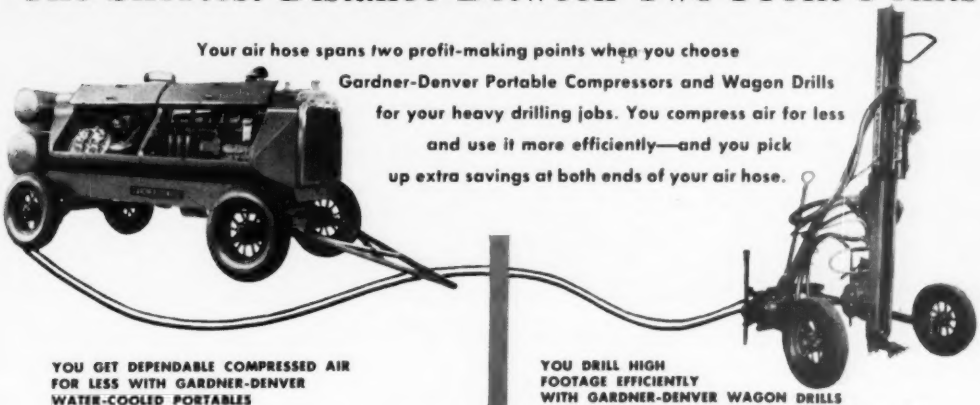


Chart shows relative stability of dynamite prices since 1935, as compared with prices of other manufactured goods. 1935-39 values = 100.

HERCULES POWDER COMPANY
INCORPORATED

Explosives Department, 990 King St., Wilmington 99, Del.

The Shortest Distance Between Two Profit Points



Your air hose spans two profit-making points when you choose Gardner-Denver Portable Compressors and Wagon Drills for your heavy drilling jobs. You compress air for less and use it more efficiently—and you pick up extra savings at both ends of your air hose.

YOU GET DEPENDABLE COMPRESSED AIR FOR LESS WITH GARDNER-DENVER WATER-COOLED PORTABLES

- Fully water-cooled compressor cylinders assure proper lubrication in cold weather—cooler operation in hot weather.
- Two-stage compression delivers full capacity at any altitude.
- High efficiency air cleaners protect against wear.
- Deep oil sumps in engine and compressor provide positive lubrication on hills.

YOU DRILL HIGH FOOTAGE EFFICIENTLY WITH GARDNER-DENVER WAGON DRILLS

- Very flexible — easily adjusted for faster hole spotting.
- Handy controls enable the operator to drill more efficiently.
- Powerful automatic blowing keeps the deepest holes clean—encourages more frequent cleaning for faster drilling.
- Long steel changes reduce steel handling time.
- Write for further information.

SINCE 1859

GARDNER-DENVER

Gardner-Denver Company, Quincy, Illinois

In Canada: Gardner-Denver Company (Canada), Ltd., Toronto, Ontario

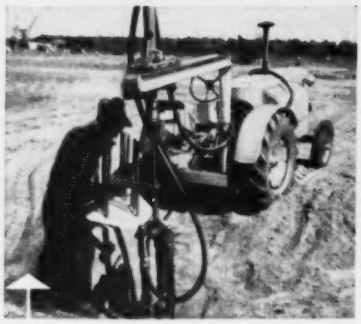
THE QUALITY LEADER IN COMPRESSORS, PUMPS AND ROCK DRILLS

LE ROI

TRACTAIR

LE ROI GIVES YOU MORE FOR YOUR MONEY

Mobildrill — A light-weight Le Roi-CLEVELAND wagon drill unit mounted on Tractair. Costs about half of what you would pay for separate compressors and rock drills to do same work. Its all-around usefulness makes drilling faster, easier. Quickly pays for itself out of savings.



Tamping — Tractair with Le Roi-CLEVELAND Multiple Tamper and work-saving air feed keeps up with three men shoveling or a backfilling tractor. You not only get faster, easier tamping, but also better compaction and lower costs.

Loading — Front-end loader can be attached to Tractair in only a few minutes. Boom combines bucket and crane. Crane folds back out of way, when not in use. Bucket holds 10½ cu. ft. — lifting capacity is 1000 lbs. Lifting capacity of crane is 800 lbs.

with Backhoe

cuts trenching costs for Illinois man . . . combines air power, digging power, and mobility, to do former two-day job in only half a day!

Your digging job too small for a power shovel? Too big to do by hand economically? Then, mister, you're money ahead with a Le Roi Tractair-Backhoe! It's a hydraulic backhoe attachment mounted on a Tractair, Le Roi's combination 35-hp tractor and 105-cfm compressor — you get both air power and digging power in a single piece of equipment.

Tractair-Backhoe units are saving money for contractors every day. Take John Proszek, plumbing contractor of Chicago, Illinois: He uses a Tractair-Backhoe to dig two ditches 60' long x 6½' deep for new home-service connections — and does in half a day what it took two days to do before!

The versatility of Tractair helps you do many jobs with greater speed and economy. Its *air power* lets you break through pavement or frost — run air tools. Its *digging power* lets you dig as deep as 7' — cut through hard ground that a pick and shovel can't penetrate — keep the bottom of a ditch perfectly level — dig straight-end walls and square corners.

But that's only part of the Tractair story. There are other attachments you can use to multiply Tractair's usefulness and hold down your investment in special equipment. With Le Roi-CLEVELAND air tools, you can break pavement, drill rock, dig clay, tamp fill, etc. With a front-end loader (it has 8 accessories you can interchange quickly), you can load, lift, backfill, plow snow, etc.

Ask your nearby Le Roi distributor to demonstrate a Tractair. Write today for job-data sheets and bulletins on Tractair.

T-24

Compressors
Tractair
Rock Drills
Engines . . .

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MORE UTILITY! MORE PROFIT!

Backfilling — A backfill blade adapts the versatile Tractair for such jobs as filling trenches, light grading, and other light dozing work — anywhere along the job site. Backfill blade is 6' wide, moldboard is 2'8" high. Maximum lift above ground is 1'4".

Drilling, Breaking, Digging — Tractair puts air power to work running Le Roi-CLEVELAND air tools. Here, Tractair operates a clay digger, to speed up trenching. Tractair can be used also to run Le Roi-CLEVELAND breakers, sinker drills, backfill tampers.

Earth Drilling — Tractair with Utility Boom operates air motor-driven earth auger up to 16" diameter — speeds up anchor-hole digging and other earth-drilling jobs. It's another way Tractair gives you extra hours of service by doing the work of specialized equipment.

1200 c.f.m.

Here's an efficient, dependable set-up for a job requiring 1200 cubic feet of air a minute — two CP Model 600 Diesel-driven PORTABLE AIR COMPRESSORS.

Whenever less air is needed, however, the CP Gradual Speed Regulator takes care of smaller demands by reducing engine speed proportionately, minimizing wear and maintaining peak economy.

The wide range of CP time-tested gasoline and Diesel-driven Portable Compressors — from 60 c.f.m. to 600 c.f.m. — permits the selection of the most suitable equipment for any particular kind of job.

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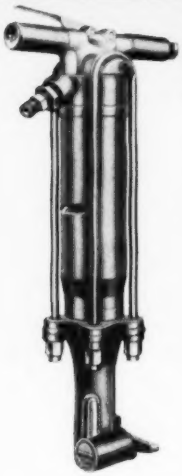
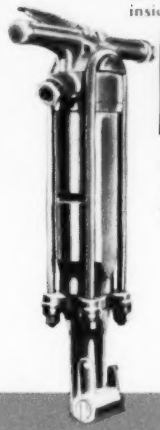
CP Fiftieth ANNIVERSARY

K ...is for the Knockout power in JOY PAVING BREAKERS



K-89 ... New Super heavyweight

There's real knockout power in this 90 lb. super breaker. The K-89 is designed to speed up demolition of those extra tough-and-heavy reinforced concrete sections, etc. Like all Joy SILVER STREAK Paving Breakers, the K-89 is cadmium-plated inside and out, which prevents rusting, eliminates scoring and aids lubrication.



K-81 ... heavyweight

Handles tough demolition jobs economically and efficiently—breaks more concrete because it strikes more and heavier blows, and because it's easier to hold. Outstanding features of the K-81 include the exclusive Joy "Dual Valve," flat-sided cylinder for easy holding against operator's leg, replaceable chuck bushings, "U" type side rods and rugged cam-type retainer.

K-61 ... medium weight

Specially suited for thin-section concrete and other light demolition jobs—hard-hitting and easy-handling like the K-81, but lighter in weight. Many of the parts, such as the chuck housing, chuck bushing and throttle, will fit both the K-61 and K-81—a considerable saving in repair parts stock.

The **THRIFTY JOY DUAL-VALVE**
Makes Air Do More Work!

Get the facts about Joy paving breakers—also Joy compressors, rock drills, wagon drills, core drills, hoists, spaders, trench diggers, etc. See your nearest Joy office or distributor.

K-31 ... lightweight

Only 30 lbs.—a powerful, easy-handling little breaker that's ideal for light demolition and all work where the operator must support the entire weight of the tool, or where footing is not solid, as on scaffolds.

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Maximum Strength — Minimum Weight in this exclusive two-section shovel boom. Lower section, rigidly connected to the A-frame, has ample strength to take shock loads. There is no torsion in the tubular handle . . . it is free to rotate in the cylindrical saddle block. Independent rope crowd with crowd machinery on the main deck means low swing inertia and faster cycles.

Dual Twin Hoist Ropes provide steady, positive, digging action. Hoist power is automatically concentrated at the part of the dipper lip where it is most needed — power application that is unmatched for rock digging.

Quick-Action Propel — The 150-B's propel machinery can be quickly engaged for faster move-ups or for getting away from slides. Less time lost in moving pays off in higher output.

Heavy-Duty Construction means less downtime, lower maintenance costs. Larger, stronger lower works stand up to rough quarry duty. Box-section caterpillar treads have separate paths for rollers and driving tumblers. Treads stay in adjustment longer and resist wear better.

These big advantages, plus improved Ward-Leonard rotating variable voltage control, mean faster cycles and higher output in hard digging. In addition, the 150-B is readily convertible to independent-motor powered dragline service.

1141L52C

● **Digging and Loading Limestone** in this Ohio quarry, the new 150-B is giving its owner topnotch performance. "We're obtaining very good results," he reports.